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An Organic Thin Film Laser Diode: A New and Novel Light Source

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13. ABSTRACT *(Maximum 200 words)*

This ONR program was focusing on the development of an entirely new diode laser, based upon electroluminescent organic thin films. During these three years, important milestones have been reached towards the demonstration of the first organic laser diode: (i) demonstration of electroluminescence from an organic channel waveguide device fabricated on glass and on Si. (ii) optical gain in excess of 10^4 cm^{-1} measured in a pure solid state conjugated polymer. (iii) fabrication of feedback structures with 0.2 μm resolution. With the synthesis of new compounds and their characterization (determination of HOMO and LUMO levels), the performance of organic light emitting devices could be continuously improved. Current devices exhibit external quantum efficiencies as high as 3 % with a stable aluminum cathode. Output light levels in excess of 45,000 cd/m^2 (500,000 cd/m^2 in pulsed regime) are measured at this stage and are getting close to the levels required to achieve gain in electrically injected structures. Finally our research efforts have led to the recent demonstration of optically pumped integrated organic laser diodes using several configurations. Simultaneously, we have developed a complete theory of optical absorption in PPV and determined the origin of photo-induced absorption in this material and other π-conjugated polymers.

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Final Technical Report

Our proposal to ONR # N000149410322 focused on the development of an entirely new diode laser, based upon electroluminescent organic thin films. During this three-year program important milestones have been reached towards the demonstration of the first organic laser diode:

- first demonstration of electroluminescence from an organic channel waveguide device fabricated on glass and on Si. Lateral confinement could be defined by either etching and filling a trench in photoresist or by changing the refractive index of the active polymer by photobleaching using UV light. Electroluminescence could be demonstrated in these waveguides and 3 dB/cm propagation loss was measured.

- optical gain in excess of 10^4 cm^{-1} has been demonstrated in a pure solid state conjugated polymer. The gain dynamics was fully characterized with picosecond resolution.

- feedback structures with 0.2 μm have been fabricated.

Our ultimate goal to demonstrate an electrically organic laser diode remains to the best of our knowledge a challenging task. However, our research efforts have initiated the recent demonstration of **optically pumped organic laser diodes**. Our advances in material development and characterization made during this program had a strong impact on the integrated laser structures that we develop currently under ONR funding. Current devices exhibit external quantum efficiencies as high as 3 % with a stable aluminum cathode. Output light levels in excess of 300,000 cd/m^2 are measured at this stage and are getting close to the levels required to achieve gain in electrically injected structures.

In addition, during our three-year program, we have completed the following tasks that have led to a gradual increase of the external quantum efficiency of our organic light emitting devices:

- fabrication of a state-of-the-art sample preparation unit for organic films under controlled atmosphere
- screening of a significant number of organic molecules for hole transport, light emitting, and electron transport layer
- synthesis of new compounds, including soluble blue-green metalloquinolates, and new electron transport quinoxaline derivatives
- determination of the HOMO and LUMO positions of luminescent and transport materials
- developed a complete theory of optical absorption in PPV and determined the origin of photo-induced absorption in this material and other π-conjugated polymers.

- Calculated polaron binding energies for various electron and hole transport materials. Demonstrated that the magnitude of the electron and hole polaron binding energies determines whether a given material is electron or hole carrier.

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